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EXPERIMENTAL PRODUCTION OF ILLUSORY (FALSE) MEMORIES IN RECONSTRUCTIONS OF NARRATIVES: EFFECT SIZE AND POTENTIAL MEDIATION BY RIGHT HEMISPHERIC STIMULATION FROM COMPLEX, WEAK MAGNETIC FIELDS

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This experiment was designed to discern the proportion of false, inferential and verbatim memories that would be included in the reconstruction, one week later, of a 5 min narrative containing ambiguous but emotional content about a little boy. After 48 subjects were administered Spiegel's Hypnosis Induction Profile, they listened to the narrative, were exposed to one of four applications of transcerebral weak, complex magnetic fields for 30 min and then given either an accurate or inaccurate short summary of the story. One week later the group who received the erroneous summary reported more false memories about the original story than did the reference group; this treatment accommodated about 40% of the variance in numbers of false memories. Only an indicator of electrical lability within the temporal lobes (but not hypnotizability) was strongly associated with the numbers of inferential memories but not the numbers of false memories. The group that received transcerebral stimulation over the right hemisphere by a complex magnetic field and the erroneous summary reported three times the numbers of false memories compared to the other groups. Whereas verbatim memories showed a strong primacy effect inferential memories exhibited a strong recency effect ($\eta^2 = .66$).

Keywords: False memories; Hypnotizability; Long-term memory; Magnetic fields; Recency-primacy

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INTRODUCTION

Although illusory or false memories have received increased attention (see Loftus, 1993) their occurrences appear to be natural characteristics of the human being's capacity to reiterate the stored representations of experience. False memories, defined as remembering words not presented in word lists, can be easily induced experimentally (Roediger and McDermott, 1995). False memories, as inferred by the alteration in autobiographical details from childhood following an experimental manipulation, are also relatively easy to induce in normal people (Pendergrast, 1995; Tulving, 1983). Considering the dominant role of the *right* prefrontal lobe (Buckner and Petersen, 1996; Wheeler, Stuss and Tulving, 1997) in the reconstruction of episodic and autobiographical memory one would expect these representations to be dominated by inferences about past events and to be influenced by the emotive quality of the details provided *after* the original experience.

The present study was designed to answer three questions. First, if false information is given 30 min after normal subjects listen to a 5 min narrative, what proportion of reconstructed memories about the narrative reconstructed one week later will contain false details? Neither all memories will be erroneous nor will all memories be veridical. Second, does the suggestibility of the subjects affect their propensity to include these false details in the reconstructions of the memories? In otherwords, does the capacity to infuse images evoked by listening to narratives affect the numbers or proportions of false memories? Third, can the application of complex magnetic fields, sufficient to alter suggestibility (Tiller and Persinger, 1994), over either the left hemisphere, right hemisphere or both hemispheres, differentially influence the accuracy of the reconstruction of the narrative?

Recent research has indicated that transcerebral application of magnetic fields with strengths in the μT range (similar to intensities generated near personal computers) rather than the mT range (Trimmel and Schweiger, 1998) can affect memory (Michaud and Persinger, 1985; Persinger and Nolan, 1985; Richards, Persinger and Koren, 1996) and electroencephalographic patterns (Persinger, 1999; Persinger, Richards and Koren, 1997) if the complex shape and interstimulus intervals for these fields simulate brain activity (Cook, Koren and Persinger, 1999; Stewart and Persinger, 2000).

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MATERIALS AND METHODS

A total of 24 men and 24 women, between the ages of 19 and 26 years, volunteered as subjects. All displayed a right hand preference for writing. Although the subjects were informed they could withdraw from the experiment at any time, they were also told they would receive the 2 point bonus mark for an introductory psychology course in which they were enrolled only if they completed both components of the study.

All of the subjects had been administered the Personal Philosophy Inventory (Persinger and Makarec, 1993) between two weeks and six weeks before the experiment. The complex partial epileptic-like symptoms scale (16 items) or CPES that has been significantly correlated with the proportion of α activity over the temporal lobes (Makarec and Persinger, 1990) and with the "suffusion of emotional significance to sensory input" (Bear, 1979) was extracted for analysis. We have employed this measure as an inference of "temporal lobe sensitivity" and the degree to which meaningfulness is associated with experience (Persinger, 1994).

Each subject was seated in a comfortable armchair within a commercial acoustic chamber and then administered Spiegel and Spiegel's (1978) Hypnosis Induction Profile (HIP). A modified motorcycle helmet within which solenoids were embedded along the temporal plane was worn by the subject; the details of the equipment are described elsewhere (Richards, Persinger and Koren, 1993). Opaque goggles were placed over the eyes.

The subject was told a tape about a young boy named "Billy" (Dittburner and Persinger, 1993) would be played and that afterwards weak magnetic fields may or may not be applied. The story was about a boy who arrives home from school, engages in routine behaviours and then that night feels something cover him and smother him; the next morning he feels stiff and tells his mother. The experience was actually the subjective correlates of a nocturnal limbic seizure.

After the door to the chamber was closed, the 5 min tape was activated. At the end of the tape the subject was assigned by predetermined sequence to one of four conditions. The subject was exposed over either the left hemisphere, right hemisphere or both hemispheres to burst-firing (see Richards *et al.*, 1993, for graphic display) magnetic fields (1 μT, range 0.5 to 2 μT), generated by a

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computer, for 1 sec every 4 sec for 30 min; subjects in the fourth group received no field (sham controls). At the end of the session, the experimenter entered the room, removed the goggles and asked the subject to complete a brief exit questionnaire concerning their experiences. This 30 min latency was selected so that any transient hippocampal (electrical) component from the narrative would have been minimal and that the subject would have entered the stage of "intermediate" memory that has been show to be affected by weak magnetic fields (Persinger and Nolan, 1985; Thomas and Persinger, 1997). Completion of the questionnaire was considered competitive stimuli for any residual imagery associated with the Billy story.

Following completion of the questionnaire, the subject listened to a taped 60 sec summary of the 5 min narrative. Half the numbers of subjects (equal numbers from each magnetic field condition and equal numbers of men and women) were given an accurate summary while the other subjects were given a summary that contained 10 errors (see Appendix I). The subjects were told they must return in a week for additional testing although no specific reference to the requirement for recollection was given. Not more than two subjects were tested per day. When the subjects returned one week later they were asked to write all of the details of the narrative.

The narrative was scored against a template that divided the 5 min story into 257 ideas (in a manner similar to the Wechsler Memory Scale). However the class of memory was designated as verbatim (direct recall), inferential (or attributional), or intrusive (false). A statement such as "the boy stared out of the window because he was sick" when the actual phrase was "the boy faced the window" would be an example of an inference. An intrusion or false memory was an event or process that was never contained within the original story. The total numbers of verbatim, inferential and false memories were tabulated for each subject for each 1 min of the original narrative. The inter-rater reliability for this method has been above 0.90. The inter-rater reliability for this experiment for each of the three types of memories for the 5 blocks from 4 subjects, randomly selected from the pool, ranged between 0.88 and 0.92.

The total numbers of verbatim, inferential and false memories and the proportion of these memories for each subject (*i.e.*, the numbers of verbatim, inferential or false memories, divided by the total numbers

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of memories for the narrative), in order to accommodate individual differences in total memory capacity, were employed as measures. The first analyses were three way analyses of variance (hemisphere of stimulation; accurate *vs.* inaccurate summary of story; gender). After the shared variance between each of the memory scores and the subjects' scores for Hypnosis Induction Profile (HIP) or the Complex Partial Epileptic-like Scale (CPES) had been removed (covaried), the three-way analyses of variance were completed again. A four way analysis of variance with two levels repeated (the five, one min blocks and the three types of memories) and three non-repeated measures was also completed. These and ancillary analyses utilized SPSS software.

RESULTS

The means and standard deviations for the total numbers of verbatim, inferential, and false memories for this experiment are shown in Table I. Three way analysis of variance (hemisphere of field application; true–false summary of story; sex) for each of the types of memories indicated that the most powerful statistically significant effect [$F(1,32) = 32.76$, $p < .001$; $\eta = 0.64$] was for the numbers of false memories. The group that had received the brief summary that contained erroneous information about the narrative during the last

TABLE I Means, SD and η^2 values for the proportion of verbatim and inferential memories and intrusions (false memories) one week after subjects had been given accurate or inaccurate "cognitive restructuring" following an emotional narrative

	Experimental condition				
	Accurate		*Inaccurate*		
Measure	*M*	*SD*	*M*	*SD*	η^2
Numbers of memories					
Verbatim details	11.4	8.7	11.9	7.4	1%
Inferential details	30.7	14.1	32.5	16.8	1%
False memories	2.7	2.2	7.7	4.0	37%
% of individual's total					
Verbatim details	23.4	11.2	22.3	10.0	1%
Inferential details	68.9	8.2	60.9	11.1	15%
False memories	7.7	6.7	16.9	9.2	25%

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few min of the session included more false memories within their reconstructions of the story one week later. Women also reported significantly [$F(1,32)=6.63$, $p=.01$, $\eta=0.31$] more false memories ($M=6.1$, S.E.M. $=.8$) then did the men ($M=3.6$, S.E.M. $=.9$). Neither these main effects nor the contributions from the transcerebral stimulation were statistically significant for the numbers of verbatim or inferential memories.

The only statistically significant interaction [$F(3,32)=3.01$, $p<.05$] occurred between the hemisphere over which the magnetic fields were applied and the type of information (accurate, inaccurate contained within the summary of the story) for the numbers of false memories. *Post hoc* analysis indicated that the primary source of this interaction was the greater numbers of false memories for the subjects who had received the summary containing errors after application of the field over the right hemisphere ($M=9.0$, $SD=1.6$) compared to the other three conditions (sham, left side, bilateral) who received the erroneous summary and all four conditions that received the accurate summary (all means between 1.4 and 4.8).

To discern if the subjects ($n=10$) who actually included the erroneous details (in parentheses in Appendix I) from the summary in their reconstructions were the primary source of the effect, their scores were compared to the subjects ($n=14$) who received the erroneous summary but did not report any of these specific details. There were no statistically [all $dfs=1,22$, $F<2.00$] significant differences between these two groups with respect to any of the types of memories. The groups did not differ with respect to their scores for either the Hypnosis Induction Profile [grand mean $=5.6$, $SD=2.3$] or Complex Partial Epileptic-like Signs [grand mean $=44\%$, $SD=20\%$]. χ^2 analysis ($\chi^2<1.50$) indicated that the distribution of men and women in the group that included the actual errors were comparable proportionally.

The means and standard deviations for the *proportions* of each type of memory relative to the person's individual memory score are also shown in Table I. Again, the group that received the erroneous summary included proportionally more errors [$F(1,32)=18.16$, $p<.001$; $\eta=.54$] in their reconstruction of the story one week later. The women's narratives also included more false memories [$F(1,32)=4.14$, $p=.05$; $\eta=.26$] then did the men.

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A five way analysis of variance with two levels repeated (the three types of memories; 5 sequential blocks of the story) and three non-repeated (sex, transcerebral stimulation and type of summary) revealed no statistically significant main effects except for the conspicuous differences between the numbers of the three types of memories ($F = 44.81$). The strongest effect was the significant interaction between the serial (5) blocks and the type (false, inferential, verbatim) of memory [$F(8, 256) = 56.53$, $p < .001$; partial $\eta^2 = 66\%$]. As can be seen in Figure 1, the source of this interaction was due to the greater numbers of verbatim memories reconstructed for the first part of the story relative to the greater number of inferential memories reconstructed for the last part of the story.

There were no statistically significant differences between men and women for either the CPES or hypnotizability scores. Because absence of mean differences between these types of scales for gender is typical

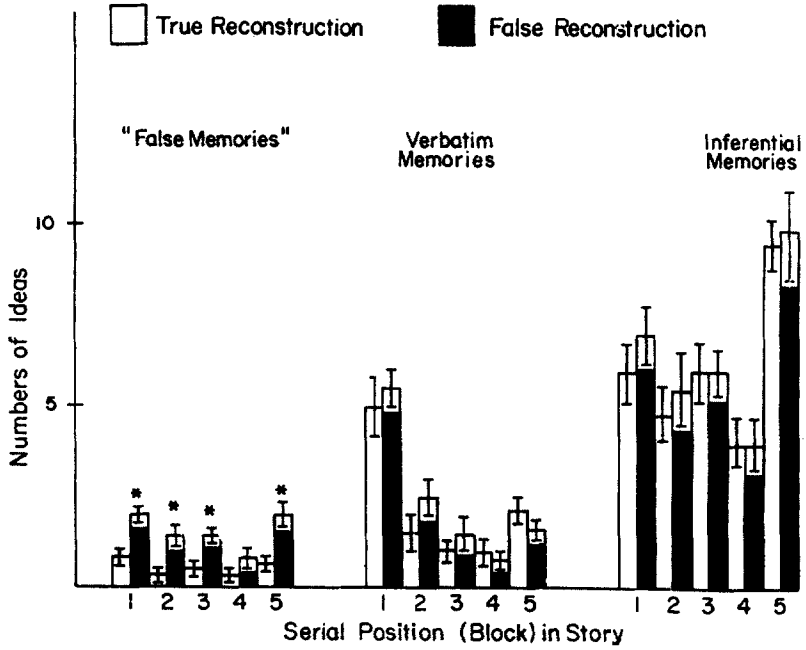

FIGURE 1 Means and standard deviations for the numbers of verbatim, inferential and false memories for each min of the 5 min narrative reconstructed one week later by the group that had received either the erroneous or accurate brief reiteration.

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TABLE II Correlation coefficients (r) between measures of the narrative and the subjects' scores for the complex partial epileptic-like signs (CPES) and hypnotic induction profile (HIP) as a function of the four treatment groups for transcerebral stimulation ($n = 12$ per group)

	Sham field		*Left hemisphere*		*Right hemisphere*		*Both hemisphere*	
	CPES	*HIP*	*CPES*	*HIP*	*CPES*	*HIP*	*CPES*	*HIP*
Numbers of								
intrusions	.28	.05	−.55*	.35	.32	.19	.23	−.15
literal recalls	.42*	0.44*	.25	−.54*	.28	.13	.12	.76**
inferences	.03	0.25	.15	−.58*	.75**	−.21*	.42*	.15
Proportions of								
intrusions	.00	−.07*	−.53*	.53*	−.13	.38	−.24	−.17
literal recalls	.48*	.38	.31	−.31	−.06	.25	−.44*	.77**
inferences	−.45*	−.29	.31	−.44*	0.25	−.63*	.61*	−.57*

*$p < .05$; **$p < .01$.

yet the magnitude and significance of the intercorrelations between the variables often vary between the sexes (Bowers and Bowers, 1972; Persinger, 1996) correlations between these variables for men and women were analyzed separately. For the women, CPES scores were correlated with numbers of literal memories ($\rho = 0.36$) and inferences ($\rho = 0.51$) and the overall numbers of memories ($\rho = 0.48$) while the HIP scores were correlated significantly with only the numbers of literal memories (0.40) and the proportion of those memories (0.43). These intercorrelations were not statistically significant for the men. The intragroup correlations between the types of memories and the inferences of suggestibility and temporal lobe sensitivity for each of the magnetic field treatments are shown in Table II.

DISCUSSION

The results of this experiment indicated that the information within a brief 60 sec "summary" of a longer 5 min narrative, experienced about 30 min previously, increased the numbers of false memories for that narrative when the subjects reconstructed its content one week later. Although the numbers of errors (10) contained with the summary were less than 10% of the total numbers of words in the summary and less than 1% of the total numbers of words in the original story, the group who had been exposed to the erroneous summary

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generated reconstructions that contained 17% false memories compared to the control group's 8%.

Further analyses indicated that only 10 of the 24 subjects who had been given the erroneous summary included at least one of these errors in their reconstructions of the narrative. These numbers were not sufficient to explain the entire 17% of the proportion of memories. Because about 8% of the details reconstructed by the control group (who did not receive the erroneous summary) contained false memories we suggest that such intrusive errors are normal features of reconstructive memory and that the inclusion of false material during the summary of a previous experience, such as the end of a counselling session, encourages the integration of these errors in subsequent reconstructions.

The subjects who received the complex magnetic field over their right hemispheres after they listened to the 5 min narrative and then later listened to the erroneous summary, included more than three times the number of false memories within their reconstructions of the story relative to any of the other field applications. These results support other data that stimulation of the right hemisphere, because of its role in the affective components of language (Budzynski, 1986), can increase the meaningfulness of images evoked by language. Some emotive images, evoked by the erroneous summary, may have been sufficient to be mislabled or perceived as "a memory" when this information was reconstructed one week later (Persinger, 1996). The potentially selective responsiveness of structures within the right hemisphere to very weak complex magnetic fields (Sandyk, 1995) must still be evaluated.

"Mislabelling" of the post-narrative errors as actual components of the narrative may not have been immediate but may have occurred during normal consolidation during the subsequent two to three days. Stimulation of the brain by the pattern of transcerebral magnetic fields employed in this study has been associated with increased "vividness" of dreaming (Persinger, 1999a, b) during the night after the exposure. The dorsal hippocampal commissure, which originates from the entorhinal cortices and other parts of the parahippocampal gyrus (Gloor, Salanova, Olivier and Quesney, 1993), would allow intercalation between the right and left limbic regions without involvement of the corpus callosum. We suggest that an above average spread of

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electrical lability from the right to the left limbic regions when the former is reactivated during dream sleep (rapid eye movement), in a manner similar to hippocampal "place cells" during paradoxical sleep (Braun, Balkin, Wesensten, Gwadry, Carson, Varga, Baldwin, Belensky and Herscovitch, 1998), might infuse the consolidation of the emotive experiences within the experimental setting, accurate or false, with greater meaningfulness.

We were surprised that the subjects' hypnotizability, as measured by the HIP, or their capacity to attach intense meaningfulness to experiences (as inferred by their scores for the CPES) were not systematically associated with the numbers or proportions of false memories. There are several possible explanations for this observation. First, the HIP scores for the subjects within this study were within the average range. Many researchers have selected primarily highly hypnotizable or "imagery prone" participants (*e.g.*, Labelle, Laurence, Nadon and Campbell, 1990). Secondly, the distinction between a "false memory" and an "inferential memory," such as the "boy was looking out the window because he was sick" rather than the original phrase "the boy, with a blanched face, was looking out the window" may vary between experimenters.

Third we evaluated hypnotizability before the introduction to the story rather than the hypnotic state while listening to the story or during its inaccurate or accurate reiteration 30 min later. Fourth, most of the studies involved with the most profound effects of hypnosis upon illusory memory (Labelle *et al.*, 1990) have involved personal (autobiographical) memory rather than impersonal (narrative) memory. Considering the differences in metabolic patterns during reconstruction of personal memories compared to the reconstructions of impersonal memories (Fink, Markowitsch, Reinkemeier, Bruckbauer, Kessler and Heiss, 1996), the frequent correlations between hypnotizability and capacity for illusory memories may be more specific to autobiographical contexts. The results of our study indicate that erroneous memories can be increased *without* the intervening role of hypnotic capacity.

Two other important results occurred in this study. The first, was the clear propensity for inferential (or attributional) processes to dominate the memory for the latter portion of a narrative and for rote processes to dominate the details of the earlier portion of the narrative.

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These qualitative differences in neurocognitive processes between the primacy effect and recency effect in a serial memory task was predicted by Sommerhoff's (1974) λ models. Previous studies involving memory for long, complex narratives have not closely examined the proportions of verbatim statements and inferential statements (Michaud and Persinger, 1985).

The second observation was the relatively strong correlation between the subject's scores that infer the person's capacity to infuse words and experiences with meaningfulness (presumably associated with a widening of affect) and the numbers of inferential memories rather than rote details. Inferences about the relationships within compositional syntax often reflect the presumptions and attributions of cause by the experient or the observer. Although they can be considered important components to intuitive thinking and creativity, they are still less then veridical representations of the original stimulus when forensic accuracy is required.

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APPENDIX I

The short review of the Billy Story. The words/phrases employed in the inaccurate version are shown in parentheses.

"Since this is an experiment involving memory, I am obliged to review the story for you briefly. This was a five minute narrative about a young boy named Billy. He lived with his parents and sister (*brother*). His bedroom was in the back (*front*) of the house and he could see the trees through the woods. One night, while having dinner with his family (*mother*), his sister started to say something, then burst into tears and ran from the table. They had been talking about lights (*UFOs*) in the sky.

When he went to bed that night, he awoke and was scared. He felt the presence of something (*his father*). Billy started to feel smothered and felt vibrations move through his body. There was an intense smell (*taste*). The next morning his body felt stiff (*relaxed*). When he went to the bathroom to brush his teeth he saw a red mark on his cheek (*arm*). Billy went to the kitchen and hugged and kissed his mother (*father*). His mother smiled and asked if anything was wrong and Billy told her what had happened. His sister began to whimper (*Billy said he wet his pants*)."

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